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LETTERS TO THE EDITOR

Deformation Sub-Structures in Aluminium

During recent years much attention has been paid to the structure of plastically deformed aluminium. Many workers have found that, during deformation, the grains dissociate into a number of small crystal blocks (cells) which are disoriented with respect to each other. Both Wood and Greenough and their collaborators have studied the influence of various experimental conditions on the cell-size. Their results may be summarized as follows.

The size of the cells formed during deformation:

(*a*) Increases with increasing temperature or decreasing rate of deformation.[1, 2, 3]

(*b*) Is independent of the amount of deformation, at least after the initial stages.[4]

(*c*) Is independent of the previous mechanical history of the specimen.[5]

(*d*) Is independent of the grain-size of the metal.[6]

(*e*) Is not markedly influenced by the presence of foreign atoms in solid solution.[7, 8]

These results suggest that the cell-size is mainly determined by the rate and temperature of deformation.

The characteristic cell-size may be attained in various ways. It is well known that if the metal is deformed under conditions such that the cell-size is less than the grain-size, the grains will dissociate into a sub-structure. However, if the deformation conditions are adjusted so that the characteristic cell-size is equal to the grain-size, no internal disruption of the grains takes place during deformation.[9] The structure of the metal, as revealed by X-ray diffraction, is the same before and after deformation.

By a further change in deformation conditions, the characteristic cell-size may be made greater than the grain-size. Recent work by the writer on both aluminium and aluminium–magnesium solid solutions has shown that under these conditions the grain-size increases during deformation. The grain growth was shown to be due not merely to the influence of temperature alone. Thus, in a deforming test-piece, the characteristic cell-size is attained at one extreme by a subdivision of the grains or, at the other, by grain growth.

It is apparent that the systematic variation in size of the sub-structure is of fundamental importance. Both Crussard [10] and Greenough and Smith [3] have interpreted the cell-size variation in terms of the dislocation density characteristic of particular deformation conditions. Wood and his coworkers, on the other hand, have suggested that the cell-size is determined by the necessity of providing sufficient interfaces to enable deformation to proceed.

Both of these explanations are unsatisfactory in the light of current work. It has become evident from much of the recently published work [10–13] that the cells arise from the formation and subsequent polygonization of deformation bands. Measurements made by the writer have shown that the width of these bands varies systematically with the temperature and rate of straining in the same way as the cell-size. When the cells are smaller than the grains, the systematic cell-size variation may find its explanation in terms of the mechanism of formation of deformation bands. On the other hand, the growth of grains to the characteristic size may possibly be explained in terms of energy considerations, minimum-energy criteria requiring the annihilation of redundant interfaces.

There exists, at present, the need for a theory which will explain the development of a sub-structure, of characteristic size, within the deforming metal. It is hoped that this survey of the relevant experimental results will further this end by promoting useful discussion.

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REFERENCES

1. G. R. Wilms and W. A. Wood, *J. Inst. Metals*, 1948–49, **75**, 693.
2. W. A. Wood and W. A. Rachinger, *ibid.*, 1949–50, **76**, 237.
3. G. B. Greenough and E. M. Smith, *ibid.*, 1950, **77**, 435.
4. W. A. Wood and R. F. Scrutton, *ibid.*, 1950, **77**, 423.
5. W. A. Wood and J. W. Suiter, *ibid.*, 1951–52, **80**, 501.
6. W. A. Rachinger, *ibid.*, 1951–52, **80**, 415.
7. G. B. Greenough, C. M. Bateman, and E. M. Smith, *ibid.*, 1951–52, **80**, 545.
8. W. A. Rachinger, *ibid.*, 1951–52, **80**, (discussion on Greenough, Bateman, and Smith's paper; to be published).
9. W. A. Wood, G. R. Wilms, and W. A. Rachinger, *ibid.*, 1951, **79**, 159.
10. C. Crussard, *ibid.*, 1948–49, **75**, 1125 (discussion).
11. R. W. Cahn, *ibid.*, 1951, **79**, 129.
12. R. W. K. Honeycombe, *ibid.*, 1951–52, **80**, 45.
13. D. McLean, *ibid.*, 1951–52, **80**, 507.

Intercrystalline Cracking of Metals

In the August 1952 issue of the *Bulletin*, Professor J. N. Greenwood contributed a note on "Intercrystalline Cracking of Metals". It happens that this same subject has also been treated by the present writer in a recent paper [1] presented before the American Society for Testing Materials at New York City.

In this, time-dependent brittle fracture was conceived to be a process whereby sub-critical micro-cracks grew eventually to critical size (by Griffith theory) through random thermal oscillations. It appears that Professor Greenwood's description of crack growth by vacancy diffusion is a much better model for brittle fracture.

In addition to fracture by this means, Zener's theory of ductile fracture [2] may be noted, as was done in Reference 1. Here fracture is pictured as occurring after micro-cracks of critical size have been formed by condensation of dislocations at some barrier (a grain boundary, for example). Positive and negative line dislocations separated by one plane of atoms, when moved to positions opposite each other, will form a crack one interatomic distance in cross-section.

Finally, Professor Greenwood notes that solute atoms can act as barriers to vacancy migration and so inhibit cracking. It is suggested by the writer [1] that precipitate particles may also act as barriers, both to vacancy and dislocation movement, and thus delay cracking. In Reference 1, a case is cited wherein the formation of a precipitate delayed fracture in an austenitic alloy under test at 1200° F. (650° C.).

It is hoped that these additional remarks will help to stimulate research on fracture—a subject receiving much less attention than the phenomena of flow or creep deformation.

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REFERENCES

1. D. N. Frey, *Amer. Soc. Test. Mat. Preprint*, 1952, (80).
2. C. Zener, *Fracturing of Metals* (*Amer. Soc. Metals*), 1948, 3.

PERSONAL NOTES

DR. J. L. ASTON has taken up a post as Lecturer in Metallurgy at the Institute of Technology, Loughborough.

MR. B. T. K. BARRY has graduated from London University with the degrees of B.Sc.(Eng.) and A.R.S.M.

MR. W. H. BOWMAN, Joint Managing Director of T.I. Aluminium, Ltd., has been elected a member of the Institution of Production Engineers.

MR. K. J. A. BROOKES, Works Metallurgist to R. G. McLeod, Ltd., has recently been awarded the B.Sc.(Eng.) degree of London University.

MR. R. A. DAY has left the Nelson Research Laboratories of The English Electric Co., Ltd., Stafford, and has taken up an appointment as Metallurgist to the Blackburn and General Aircraft Co., Ltd., Brough, East Yorks.

DR. S. F. DOREY has been elected a Vice-President of the British Internal Combustion Engine Research Association.

MR. J. M. DOUGLAS has been appointed General Manager, The Argus Foundry, Ltd., Thornliebank, near Glasgow.

MR. D. N. GIFFORD has been appointed a Director of Efco Engineering Co., Ltd., Burton-on-Trent.

MR. N. HAWKINS has left the Nelson Research Laboratories of The English Electric Co., Ltd., Stafford, and has taken a post with the British Driver-Harris Co., Ltd., Manchester.

MR. F. HOUGHTON has been elected President of the Refractories Association of Great Britain for the year 1952–53.

MR. D. E. KING has been appointed Junior Metallurgist to the Cerro de Pasco Corporation, La Oroya, Peru.

DR. J. S. LLEWELYN LEACH has been appointed a research associate in the Metallurgy Department of the Massachusetts Institute of Technology, Cambridge, Mass.

MR. B. W. H. MARSDEN has been awarded a B.Sc. degree with Second Class Honours at University College, Swansea, and has taken up an appointment with the Algama Steel Corporation, Sault Ste. Marie, Ont., Canada.

MR. K. J. MARSH has left the British Non-Ferrous Metals Research Association to become a physicist in the Research Division of the Metal Box Co., Ltd., Acton.

MR. P. R. MARSH, of the British Driver-Harris Co., Ltd., has been transferred to the parent company, Driver-Harris Co., Harrison, N.J., for a period of one year.

MR. G. J. METCALFE has left the Fulmer Research Institute on his appointment as Senior Research Metallurgist with the Precious Metals Division of The Mond Nickel Co., Ltd., Acton.

MR. J. MORRIS has graduated with Class IIA Honours from the Department of Industrial Metallurgy at Birmingham University.

MR. R. L. MORTON has been appointed Chief Metallurgist to the Consolidated Pneumatic Tool Co., Ltd., Aberdeen. He was formerly with Babcock and Wilcox, Ltd., Renfrew.

MR. E. PLAYER has been elected Chairman of the Aluminium Industry Council, in succession to Mr. H. E. Jackson.

MR. J. S. PRESTT has recently obtained a Second Class Honours Degree at the Manchester College of Technology and is now engaged as a Graduate Apprentice at the Liverpool works of D. Napier and Son, Ltd.

MR. C. E. PROSSER has been appointed Deputy Chairman of the Metals Division of Imperial Chemical Industries, Ltd. He is succeeded as Joint Managing Director, Metals Division, by Mr. M. J. S. Clapham.

MR. R. RAWLINGS has been appointed a Lecturer in the Department of Metallurgy, University College, Cardiff. He was previously in the Nelson Research Laboratories of The English Electric Co., Ltd., Stafford.

Death

The Editor regrets to announce the death of:

DR. FREDERICK JOHNSON, an Original Member of the Institute, on 1 October. Until his retirement a few years ago, Dr. Johnson was Head of the Metallurgy Department of Birmingham Central Technical College. The Institute was represented at his funeral by Mr. H. H. Symonds (Member of Council).

NEWS OF LOCAL SECTIONS AND ASSOCIATED SOCIETIES

South Wales Local Section

At a meeting held at University College, Swansea, on 7 October, Mr. CHRISTOPHER SMITH, Superintendent, James Booth and Co., Ltd., Birmingham, gave a lecture on:

Extrusion

The subject was discussed in broad detail and the characteristic behaviour of different types of materials, both copper-base and aluminium-base, in the extrusion processes was described.

Details of the equipment were dealt with briefly, and the general question of flow in extrusion and the behaviour of different materials as they flow in the extrusion process itself was discussed.

Problems arising from the effects of friction were then considered as they affect the structure of the finished extrusion, and means of overcoming difficulties arising from these effects were also discussed.

Subsequently, some practical details of actual extrusion processes in respect of relative sizes of billets and extrusions were considered, and attention was given to the common defects which arise in extrusions. The general question of die design was also discussed.

At a meeting to be held at University College, Swansea, on 4 November, Mr. F. KING, of the Northern Aluminium Co., Ltd., will describe:

The Rogerstone Strip Mill

The author will give a brief outline of the sequence of operations from the receipt of raw material to the despatch of finished products from the new Rogerstone continuous strip mill of the Northern Aluminium Co., Ltd.

The equipment used for the remelting, scalping, pre-heating, hot rolling, cold rolling, annealing, slitting, shearing, corrugating, degreasing and inspection, will be briefly described, and reference will be made to the metallurgical problems encountered in the production of sheet and strip.

Lantern slides and a short film will be used to illustrate the major items of equipment.

NEWS OF KINDRED SOCIETIES

Caustic Cracking in Steam Boilers

The Corrosion Group of the Society of Chemical Industry is to hold a symposium on "Caustic Cracking in Steam Boilers" at the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, on Thursday, 20 November 1952, from 9.45 a.m. to 12.15 p.m. and 2.0–5.0 p.m. Papers by the following authors will be presented and discussed: Dr. A. A. Berk (U.S. Bureau of Mines), Mr. P. Hamer (Imperial Chemical Industries, Ltd.), Dr. J. Lodder (Mekog, Holland), Dr. R. N. Parkins (University of Durham), M. R. Rath (Electricité de France), Mr. R. Ll. Rees (British Electricity Authority), and Dr. C. D. Weir (Merz and McLellan). Advance summaries of these papers may be obtained from the Assistant Secretary, Society of Chemical Industry, 56 Victoria Street, London, S.W.1. A buffet lunch will be available for those who notify the Assistant Secretary by 13 November.

DIARY

The Institute

19 November. All-Day Symposium on "Properties of Metallic Surfaces". (The Royal Institution, Albemarle Street, London, W.1, at 9.45 a.m. and 2.0 p.m.)

Local Sections

4 November. Oxford. "The Pressing and Sintering of Metal Powders", by Dr. J. C. Chaston. (Black Hall, St. Giles, Oxford, at 7.0 p.m.)

4 November. South Wales. "The Rogerstone Strip Mill", by F. King. (University College, Metallurgy Department, Singleton Park, Swansea, at 6.30 p.m.)

6 November. Birmingham. "Metallurgical Problems Imposed by Stratospheric Flight", by Major P. L. Teed. (James Watt Memorial Institute, Great Charles Street, Birmingham 3, at 6.30 p.m.)

6 November. London. "An Approach to the Theory of Ternary Alloys", by Professor G. V. Raynor. (The Royal School of Mines, South Kensington, London, S.W.7, at 7.0 p.m.)

10 November. Scottish. "The Properties and Engineering Applications of Electrodeposits", by R. A. F. Hammond. (Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, at 6.30 p.m.)

18 November. Sheffield. "Some Metallurgical Problems Imposed by Stratospheric Flight", by Major P. L. Teed. Joint Meeting with the Sheffield Metallurgical Association and the Sheffield Society of Engineers and Metallurgists. (Grand Hotel, Sheffield, at 7.0 p.m.)

28 November. London. Annual Dance. (4 Grosvenor Gardens, London, S.W.1.)

Other Societies

3 November. Institute of British Foundrymen, Sheffield and District Branch. "Outlook and Attitude of Management and Workers of British and American Foundries", by R. F. Horton. (Sheffield College of Commerce and Technology, Dept. of Engineering, Pond Street, Sheffield 1, at 7.30 p.m.)

4 November. Institute of Metal Finishing, Midlands Branch. "Low Cost—High Productivity in Metal Finishing". (James Watt Memorial Institute, Great Charles Street, Birmingham 3.)

6 November. Leeds Metallurgical Society. "The Production of Some of the Rarer Metals", by A. R. Powell. (Chemistry Department, The University, Leeds 2, at 7.0 p.m.)

8 November. Institute of British Foundrymen, Newcastle Branch. T.S. 35 Film—"Flow of Metal into Moulds", presented by G. W. Nicholls. (Neville Hall, Westgate Road, Newcastle-upon-Tyne, at 6.0 p.m.)

8 November. Institute of British Foundrymen, Scottish Branch. "Casting Design in Relation to Production", by J. H. Pearce and G. D. Whitehouse. (Royal Technical College, Glasgow, at 3 p.m.)

12 November. Institute of British Foundrymen, London Branch. Session on "Research" to be opened by representatives from the B.S.F.A., B.C.I.R.A., and B.N.F.M.R.A. (Waldorf Hotel, Aldwych, London, W.C.2, at 7.30 p.m.)

12 November. Manchester Metallurgical Society. "Refractories in the Non-Ferrous Metal Industry", by D. B. Tait. (Engineers' Club, Albert Square, Manchester, at 6.30 p.m.)

13 November. Institute of British Foundrymen, Lincolnshire Branch. "Casting Defects", by G. W. Nicholls. (Lincoln Technical College, at 7.15 p.m.)

13 November. Institute of Metal Finishing, North-West Branch. "Barrel Plating", by B. Jones. (Engineers' Club, Albert Square, Manchester, at 7.30 p.m.)

13 November. Liverpool Metallurgical Society. "Heat-Treatment of Steels", by R. J. Brown. (Liverpool Engineering Society, The Temple, Dale Street, Liverpool, at 6.30 p.m.)

14 November. Institution of Mechanical Engineers. Thomas Hawksley Lecture: "The Mechanism of Work-Hardening in Metals", by Professor N. F. Mott. (Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 5.30 p.m.)

17 November. Institute of Metal Finishing, London Branch. "Periodic Reverse-Current Plating", by W. F. B. Baker. (Northampton Polytechnic, St. John Street, London, E.C.1, at 6 p.m.)

18 November. North East Metallurgical Society. "Microstructural Characteristics of Corrosion in Acid-Resisting Steels", by H. T. Shirley. (Cleveland Scientific and Technical Institution, Middlesbrough, at 7.15 p.m.)

19 November. Institute of British Foundrymen, North-East Scottish Section. "Mechanization in the Foundry", by J. Aitken. (Imperial Hotel, Keptie Street, Arbroath, at 7.30 p.m.)

20 November. Society of Chemical Industry, Corrosion Group. Symposium on "Caustic Cracking in Steam Boilers". (Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, at 9.45 a.m. and 2.0 p.m.)

26 November. Institute of British Foundrymen, Birmingham, Coventry, and West Midlands Branch. "The C Process of Moulding", by J. Butler. (James Watt Memorial Institute, Great Charles Street, Birmingham 3, at 7.15 p.m.)

26 November. Manchester Metallurgical Society. "Uses of Tin in Industry", by Dr. J. W. Cuthbertson. (Engineers' Club, Albert Square, Manchester, at 6.30 p.m.)

28 November. Institute of Metal Finishing, Sheffield and North-East Branch. Open Evening Discussion. C. Wharrad in the Chair. (Grand Hotel, Sheffield, at 7.30 p.m.)

APPOINTMENTS VACANT

APPLICATIONS are invited from suitably qualified persons for the research staff of the British Cast Iron Research Association, for an investigation on the soundness of iron castings. Applicants should possess an honours degree or its equivalent, and some previous research and/or industrial experience would be an advantage. The appointments will be in the Scientific Officer (£418–£676 p.a.) or Senior Scientific Officer (£785–£980 p.a.) grades, according to age, experience, and qualifications.

Applicants should submit full details of qualifications, age, and experience to British Cast Iron Research Association, Alvechurch, Birmingham.

LARGE ENGINEERING ORGANIZATION with headquarters in the Midlands, has vacancies for work on the development of modern foundry processes, including precision casting. The posts offer considerable scope for initiative in what is a new field of endeavour on ferrous and non-ferrous alloys. Applicants should preferably have qualifications in chemistry or metallurgy, and some foundry experience would be an advantage. Salary will be in the range of £700 to £1000, depending upon experience and qualifications. Write giving full particulars to Box No. 341, The Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

METALLURGIST is required for central research department. The work consists of research on a variety of problems connected with hot and cold working and heat-treatment of steels. Applicants should be between 25 and 35, have a good metallurgical degree and, preferably, research experience. Salary according to experience and qualifications. Apply in writing to Tube Investments, Ltd., Dept. of Development and Research, Plume Street, Aston, Birmingham 6.

METALLURGIST, preferably with experience of X-ray-diffraction work, is required by central research establishment. The work consists principally of research on light metals. Applicants should be between 25 and 30, have a good honours degree, and, preferably, post-graduate research experience. Salary according to experience and qualifications. Apply in writing to Tube Investments, Ltd., Department of Development and Research, Plume Street, Aston, Birmingham 6.

METALLURGIST required for Scottish Factory of progressive light engineering company manufacturing plain bearings and at present embarking on an expansion programme. He will be required to conduct original investigations into a variety of problems arising from the latest developments in non-ferrous processes. The man appointed will be given the necessary facilities and support. A laboratory already exists for chemical, metallurgical, and mechanical work. The company seeks a young man with an honours degree in applied science, preferably metallurgy, plus an ability for fundamental thought. A good commencing salary will be paid and there are excellent prospects. There is a good possibility of a house being available about twelve months after appointment. Applications should be addressed to the Personnel Manager, The Glacier Metal Co., Ltd., No. 3 Factory, Kilmarnock, Ayrshire.

THE MOND NICKEL CO., LTD., has vacancies on its Development and Field Service staffs for METALLURGISTS with experience in the application of stainless and other alloy steels in the engineering and chemical industries, and in the welding of ferrous and non-ferrous materials. Apply, stating qualifications, experience, salary required, &c., to Manager, D. and R. Dept., The Mond Nickel Co., Ltd., Sunderland House, Curzon Street, London, W.1, marking envelope "Confidential".

THE MOND NICKEL COMPANY, LONDON, require senior assistant in Technical Information Section for abstracting and information work, mainly in metallurgy and engineering. Technical or scientific qualifications, experience in special library work, and a reading knowledge of French and German desirable. Apply, giving age, qualifications, experience, salary required, &c., to Manager, D. and R. Dept., The Mond Nickel Co., Ltd., Sunderland House, Curzon Street, London, W.1. Mark envelope "CONFIDENTIAL T".

REQUIRED for works in the Neath area, experienced metallurgical assayer. Applicants should be not less than thirty years of age and have had about ten years' experience in a metallurgical laboratory. They should be capable of fast and accurate routine analyses. Reply, giving full details of training, experience, and present salary, stating age and whether married or single, to Box H.236, c/o Streets, 110 Old Broad Street, London, E.C.2.

APPOINTMENT WANTED

GRADUATE METALLURGIST, having three years' experience of refining, alloying, and casting non-ferrous metals and alloys in India, desires appointment in similar capacity in England. Box No. 340, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.